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TITLE THE LAWRENCE LIVERMORE LABORATORY TWO-STAGE, LIGHT-GAS GUN

AUTHOR(S) A. C. Mitchell and W. J. Nellis

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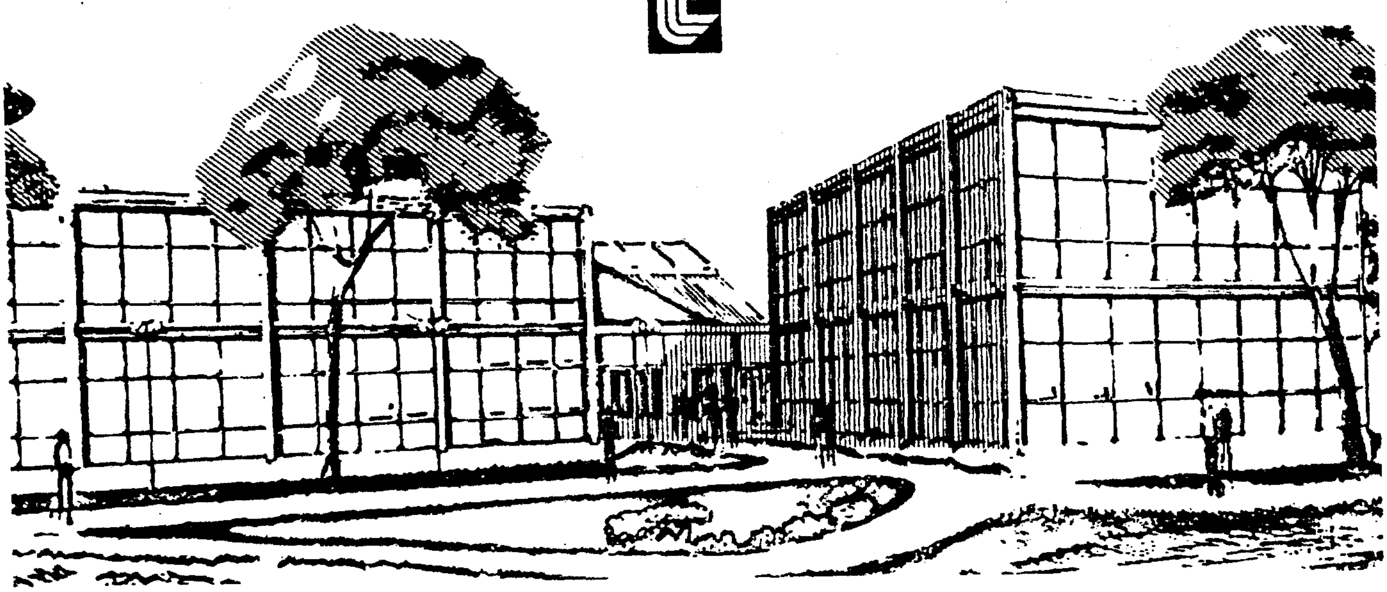

DISCLAIMER

THE LAWRENCE LIVERMORE LABORATORY

TWO-STAGE, LIGHT-GAS GUN*

A. C. Mitchell and W. J. Nellis
Lawrence Livermore Laboratory
Livermore, California 94550

I. INTRODUCTION

The Lawrence Livermore Laboratory two-stage gun was obtained from General Motors Corporation in the early 1970's. The dimensions and operation have been described.[1] The facility is used primarily for high pressure and high temperature material property studies and can achieve pressures about twice what can be realized with high-explosive planewave systems.

II. GUN FIRING PARAMETERS

Most shots use a 29 mm inner diameter launch tube and 12-25 g projectiles. Firings typically use 30 moles or 0.85 MPa of H_2 in the pump tube. The piston weighs 6.8 kg and the rupture valves burst at about 140 MPa. Projectile velocity is achieved by varying the powder load which ranges up to 1.35 kg. The pressure pulse is similar to that for a larger two-stage gun.[2] The launch tube and target chamber are evacuated to a few micrometers of Hg pressure prior to each firing. Under these conditions maximum velocities for 15 and 24 g projectiles are 7.3 and 6.8 km/s, respectively. Velocities as low as 1.5 km/s have been achieved.

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III. PROJECTILE

The standard projectile[3] is illustrated in Fig. 1 and consists of a metal plate 1-3 mm thick and 25 mm in diameter hot-pressed into a polycarbonate cylinder. This composite is then inspected under ultraviolet light to insure that it is stress-free. A cap of polyethylene is pressed over the end of the polycarbonate opposite the metal to act as a gas seal. This design requires a minimum of machining and the polycarbonate does not interfere with the experiment. As indicated in Fig 1, the length to diameter (L/D) ratio is less than 1. However, very little tumbling occurs in the 30-40 cm free-flight distance between the muzzle and the target. Specifically, the angle of tilt between the impactor and the target is $\sim 3^0$ or less. The degree of tilt is larger for the heavier projectiles and not very sensitive to the L/D ratio.

IV. PROJECTILE VELOCITY MEASUREMENT

Projectile velocity is obtained by measuring the distance travelled in a measured time interval. Two positions are measured by two separate radiographic images, recorded on fast-developing film. The time interval is obtained by measuring the interval between pulses from two x ray detectors located close to the two pulsed x ray sources. These sources are well collimated and about 2 m from the flight path to minimize parallax.

For this system to be successful, both x ray sources must flash when the projectile is near the center of the field of radiation. Thus, a reliable trigger system was designed consisting of a dc x ray source directed across the flight path.[4] When the projectile crosses this beam an interupt signal is generated both x ray sources are then flashed at preselected time delays determined by the expected projectile velocity. The first flash radiographic source is so close (about 8 mm) to the trigger source that it is virtually impossible for the projectile not to be observed.

The dc x ray trigger source is an x ray generator used for conventional x ray diffraction studies. The power supply can operate to 50 kV dc and 40 mA. A filter circuit was added to smooth the ripple in the full-wave rectified voltage. A molybdenum tube is used with Kα radiation at 17.5 keV.

High accuracy in the position measurements is obtained by a preshot length calibration in which radiographic film images are taken of a ruler inserted in the flight path. The centers of the two raiographs are 298 mm apart. The ruler was fabricated by machining grooves in a piece of plastic and filling them with lead. Numbers were placed on the ruler every 10 mm in the same fashion. The ruler has one division every 2 mm and the interdivision distance has been determined with an optical comparator having micrometer resolution. The differences in the readings made by the two authors of the spatial distance travelled by the projectiles on 30 shots have an average of 0.05 mm and a standard deviation of 0.2 mm. The flash x ray pulses are about 30 ns long (FWHM). However, since both pulses have a common shape, discriminator levels on a time interval meter can be set in such a way that the 40 μs or more time interval can be measured to about 10 ns. Thus, the error in the distance measurement dominates and the fractional error in the projectile velocity at the two standard deviation level is 0.4/300 = 0.0013, or about 0.1%. A pair of radiographs showing the preshot calibration and in-flight projectile is shown in Fig. 2.

V. GEOMETRY OF THE IMPACTOR SURFACE

We have recently developed a fast shockwave detection system having a time resolution of 0.3 ns.[5] This resolution has enabled us to measure the distortion from planarity of the front surface of the impactor. We have found that Ta impactors have an axially symmetric distortion in which the portion of the front surface 9 mm from the center axis leads the center by up to 10 ns at a projectile velocity of 7 km/s.[6] This maximum time interval corresponds to a spatial depth of 70 micrometers out of a total plate thickness of 1.5 mm. Typical experiments involve about 30 micrometers. Since typical shock transit times are 200 ns, the data must be corrected for the shape of the resulting shockfront in order to obtain shock velocity data accurate to 1% or better.

Experiments were performed with targets on which 13 detectors were arranged on two mutually perpendicular coplanar rows each of which were 18 mm in length. The detectors were separated by 3 mm with seven detectors on each axis mounted against a Ta plate 1 mm thick. Impactors of varying thicknesses, velocities, and materials were then characterized. Typical results from one of these shots are shown in Fig. 3. The starting time, $t = 0$, is the time the shock arrived at the first detector in the row. The observed time sequence is indicative of a front surface geometery composed of tilt of the impactor relative to the target superimposed upon an axial distortion in which the center of the impactor lags the edges. The solid lines through the data of Fig. 3 are least-squares fits to such a geometry.

In Fig. 4 the equation to which the data was fitted is derived:

$$t = \left(\frac{\tan\theta}{U_I}\right) (R_m - R) + \left(\frac{a}{U_I}\right) (R_m^2 - R^2), \qquad (1)$$

where t is the shock arrival time at the detector at R, θ is the angle of tilt of the impactor with respect to the target, R_m is the maximum radius on which a detector is positioned, U_I is the impactor velocity, and a is the amplitude of the parabola describing the shock curvature. Since the tilt is $\sim 1^0$ and the depth of the distortion is $\sim 1\%$ of the plate thickness, these geometrical effects are small and should simply add. The amplitudes of the two fits in Fig. 3 are 3.4×10^{-4} and 3.1×10^{-4}/mm. The standard deviation per detector in these fits is 0.8 ns, which is comparable to the scatter on our Hugoniot experiments described elsewhere in these proceedings. Thus, the assumption of parabolic distortion is consistent with the precision of our data.

In general we have found that projectile tilt is determined primarily by the launch tube. For a given projectile mass and velocity and a given launch tube the tilt is reproducible to a considerable degree both in terms of orientation and magnitude. In fact, we often orientate the target to compensate for expected tilt, in order to reduce the spread of detector arrival times. The parabolic distortion is determined primarily by the mass and the uniformity of areal mass density of the projectile. For example, the surfaces of Al impactors are generally planar to 1 ns, whereas Ta impact surfaces can have distortions as long as 10 ns.

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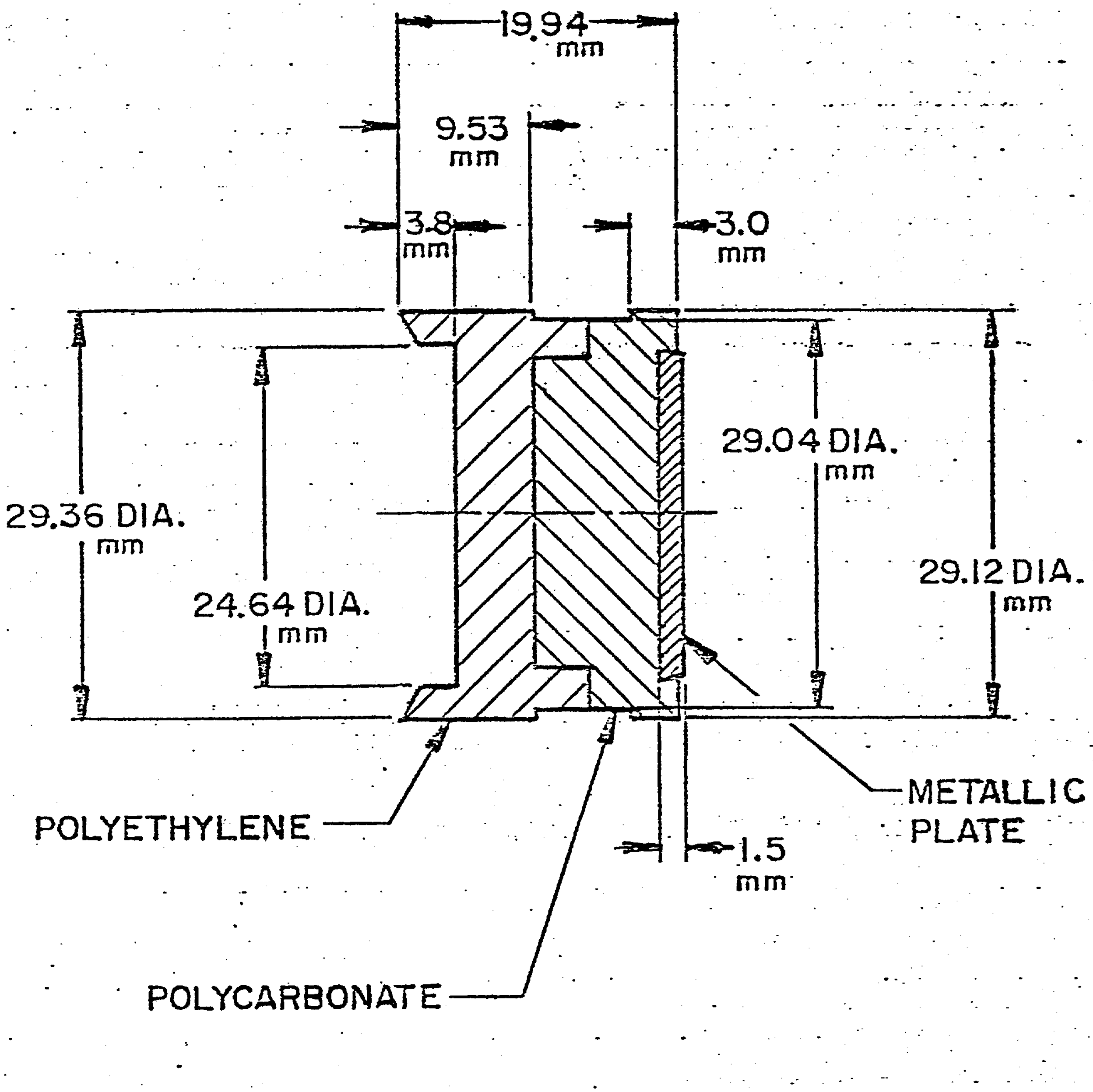


FIG. 1. Sabot with metal impact plate.

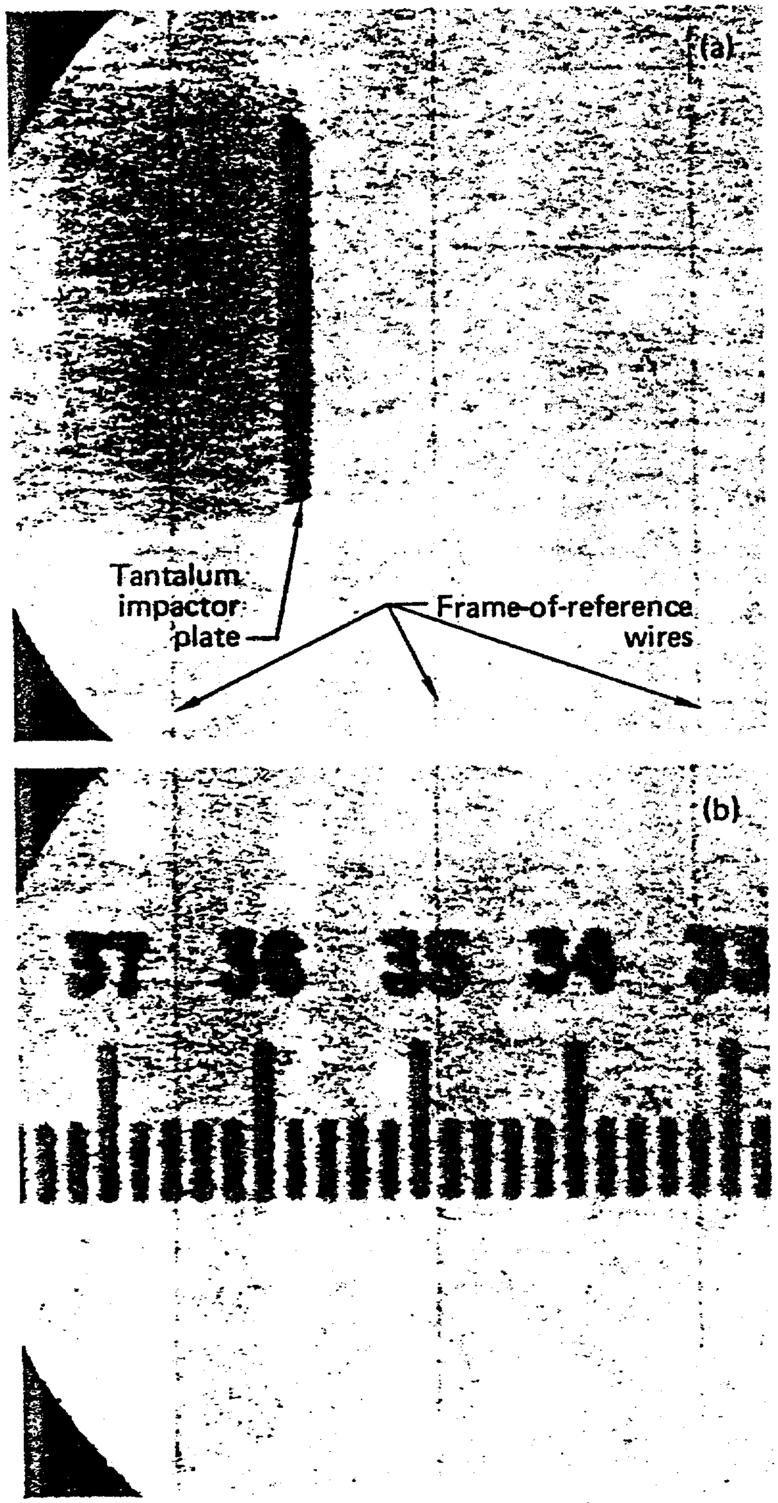


FIG. 2. Radiographs for measuring projectile velocity. (a) Projectile travelling 6.8 km/s. (b) Ruler inserted in the flight path before the shot for length calibration.

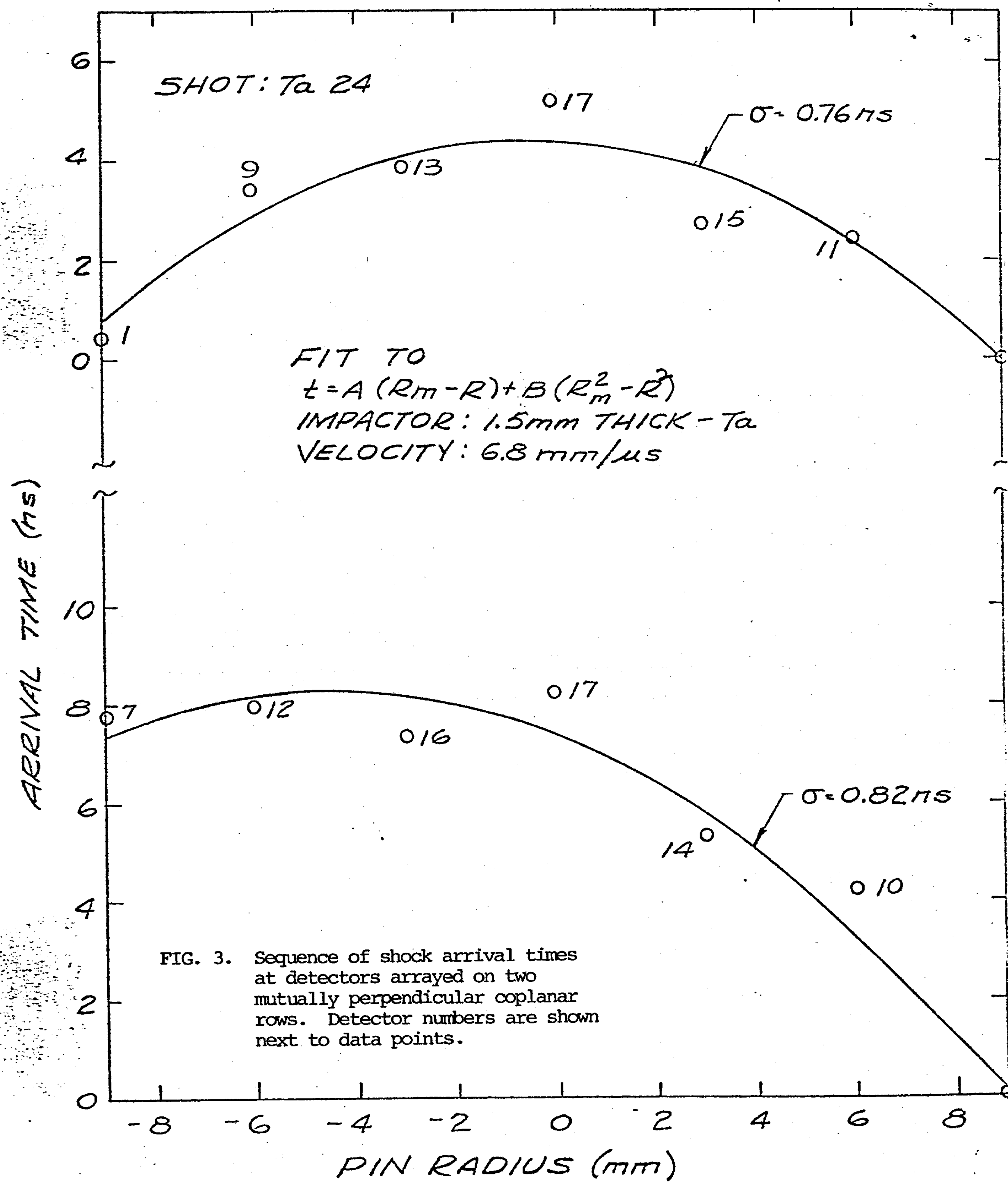
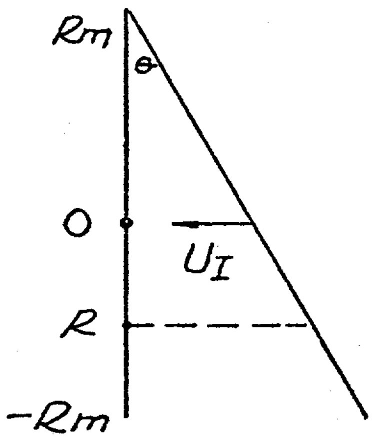


FIG. 3. Sequence of shock arrival times at detectors arrayed on two mutually perpendicular coplanar rows. Detector numbers are shown next to data points.

TWO STAGE GUN

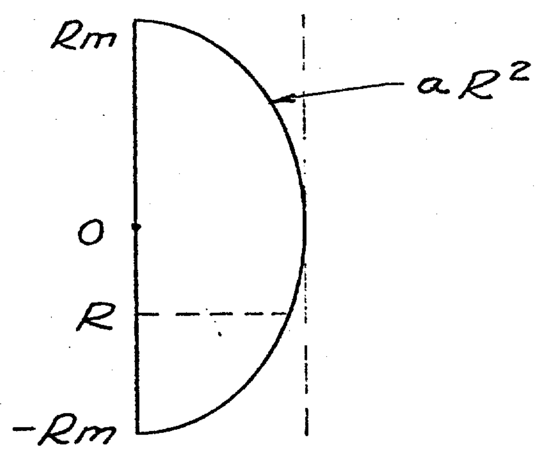
IMPACTOR PLATE TILTS & BOWS

TILT:



$$t = \frac{(Rm - R)\tan\theta}{U_I}$$

PARABOLIC BOW



$$t = \frac{a(Rm^2 - R^2)}{U_I}$$

SINCE BOTH EFFECTS ARE SMALL, THEY ADD

$$t = \left(\frac{\tan\theta}{U_I}\right)(Rm - R) + \left(\frac{a}{U_I}\right)(R^2m - R^2)$$

FIG. 4. Derivation of shock arrival times due to impactor tilt and distortion (bow).

Distribution

W. J. Nellis

A. C. Mitchell

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